PeMS
The Freeway Performance Measurement System

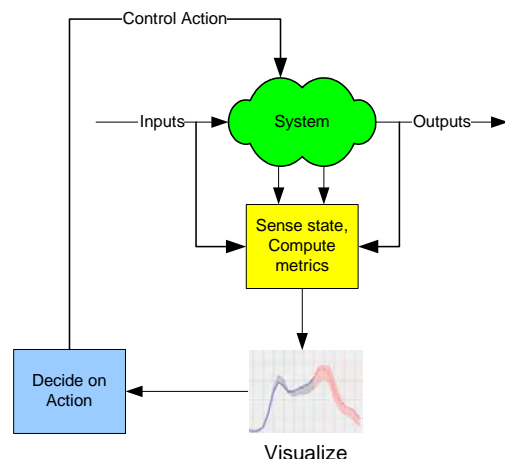### Improving Management of the Freeways

Karl Petty, Berkeley Transportation Systems, Inc.
June 15th, 2006

Systems Management

- Transportation network is a system
- At one level, vehicle hours are the input with vehicle miles as output
- There are many levels/types of inputs and outputs
- Proper collection and analysis of the outputs is necessary for efficient management and control

Control Action · Inputs · System · Outputs · Sense state, Compute metrics · Decide on Action · Visualize

"*If you cannot tell the VMT on your system yesterday, you cannot hope to manage your system today,*"

Berkele

attributed to Dolf May, 1961

Freeway Systems Management
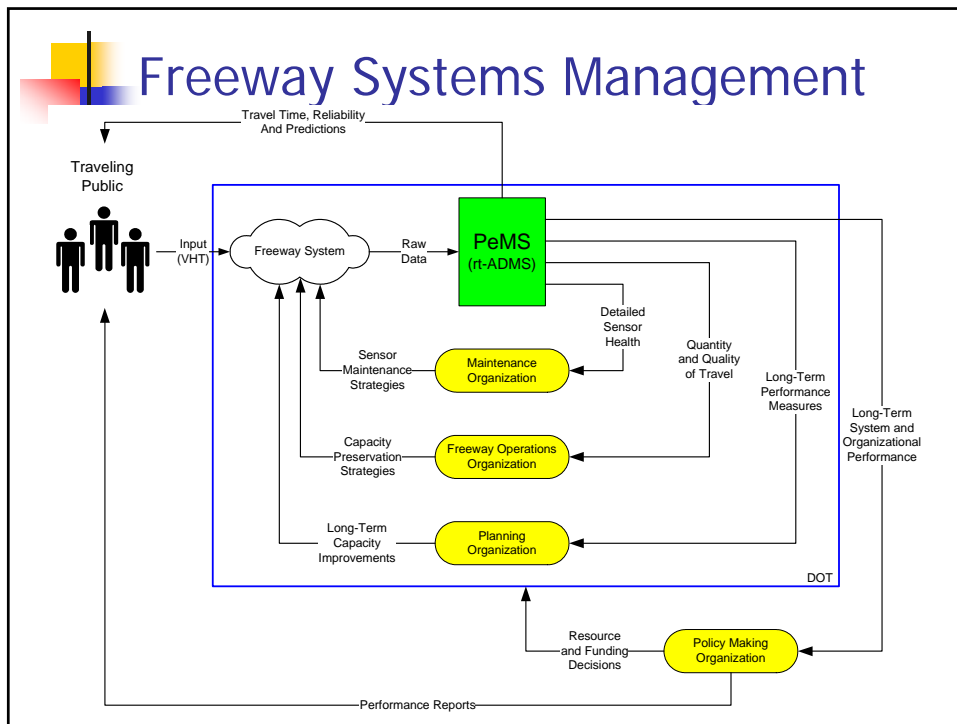
What is PeMS?

- PeMS is a real-time Archive Data Management System   (rt-ADMS)
- PeMS collects detailed freeway information
  - Fixed sensor: lane-by-lane, 20/30-second values
  - Incident: detailed reports
- Processes these values in real-time, performing:
  - Detector diagnostics
  - Imputation
  - Speed calculations
  - Aggregations
  - Performance measurement calculations
- Has a huge number of reports and tools
- Accessed via a browser
- In California:
  - Collects data from 9 districts (> 23,000 sensors)
  - Holds 4.5TB of data
  - 55 Billon samples/year

Using the PeMS Web Site

- Starting point is the Dashboards
  - Real-time Dashboard
  - Historical Dashboards
  - Detector Health
- PeMS Dashboard Characteristics
  - Actionable
    - Dashboards are tied to detailed analysis tools
  - Automatic
    - Based on data automatically collected and processed in real-time
  - Repeatable
    - Results are comparable over time and between districts
  - Internally focused
    - Meant to focus team and motivate action
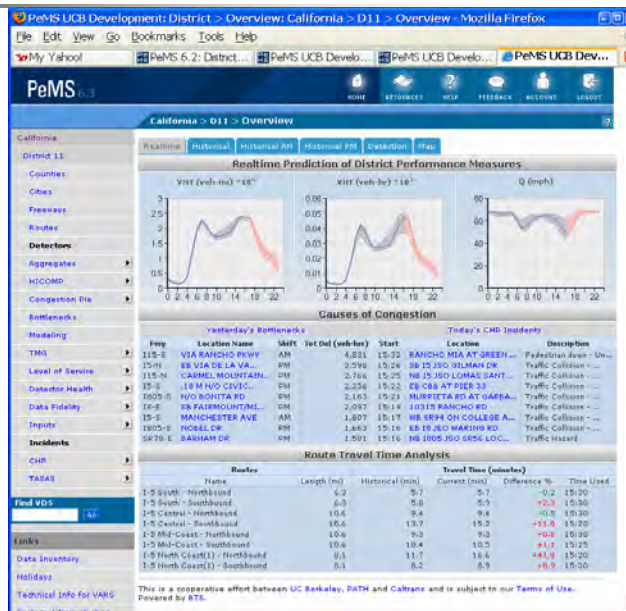   - But viewable by the public

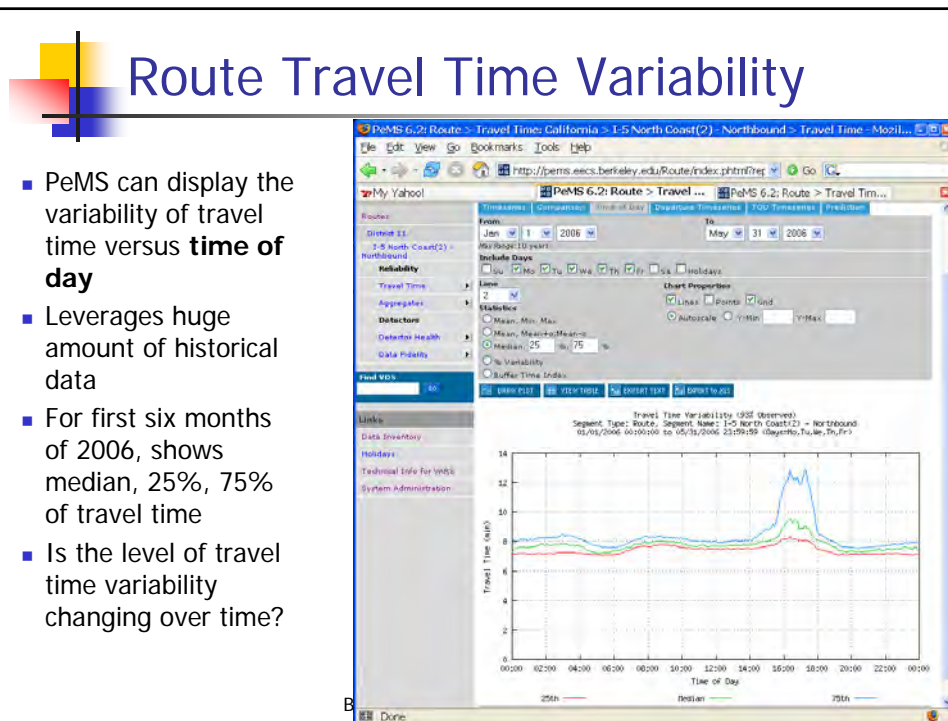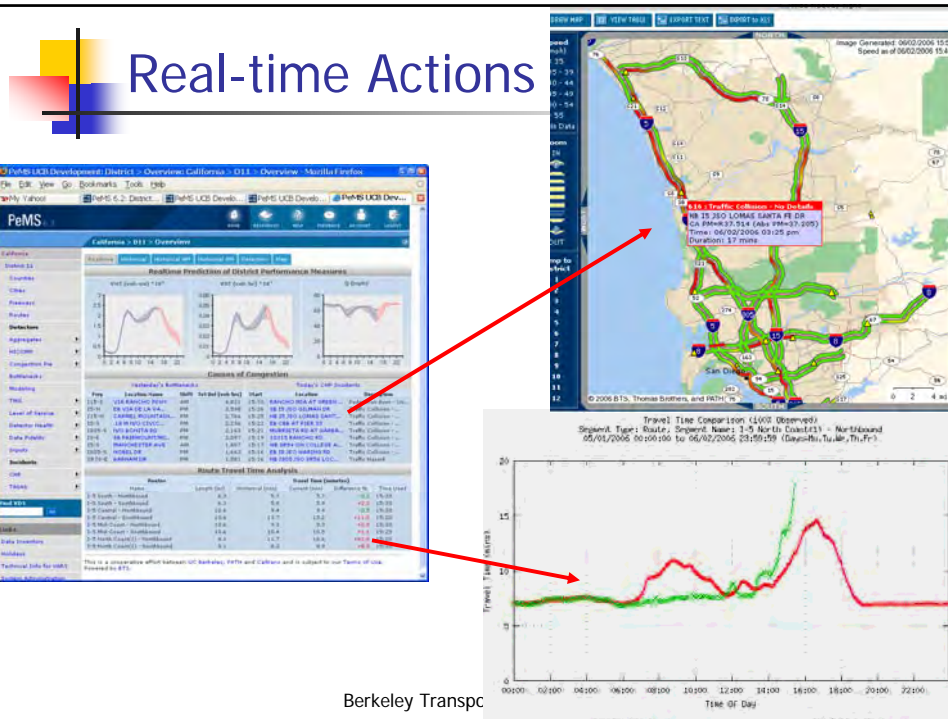(Note: based on PeMS 6.3, to be released next week)

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Real-time Dashboard

- Caltrans D11
- Snapshot of what's taking place today
- Top: Traditional performance measures
  - Measured until now
  - Historical bounds
  - Predicted for rest of day
- Middle: Causes of congestion
  - List of major bottlenecks in District
  - List of incidents from CHP
- Bottom: Mobility analysis
  - Historical travel time
  - Latest available travel time
  - Difference

Real-time Actions

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Route Travel Time Variability

- PeMS can display the variability of travel time versus **time of day**
- Leverages huge amount of historical data
- For first six months of 2006, shows median, 25%, 75% of travel time
- Is the level of travel time variability changing over time?
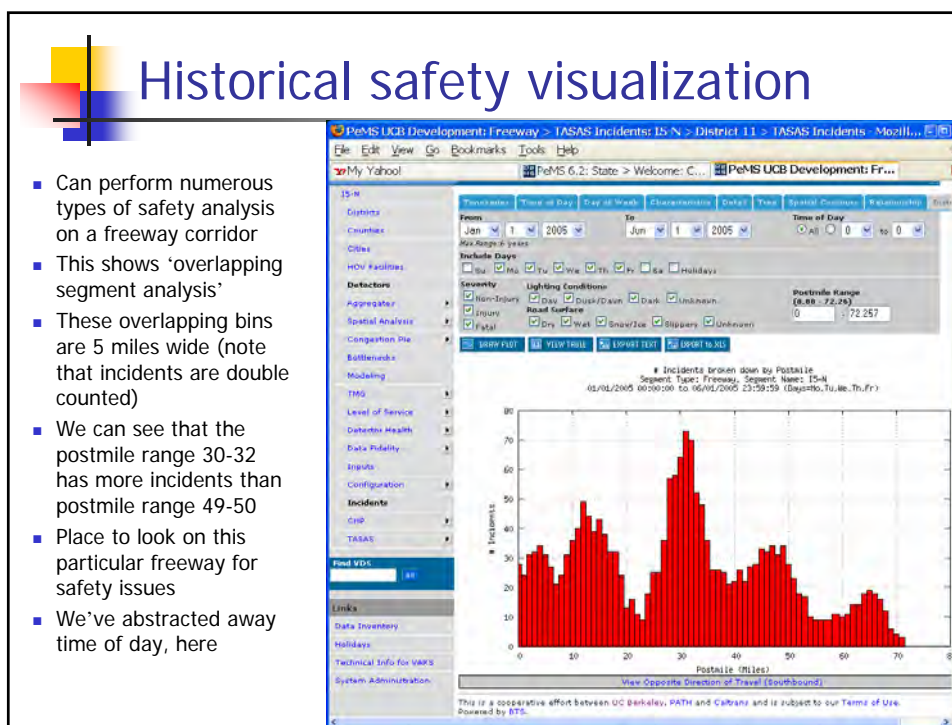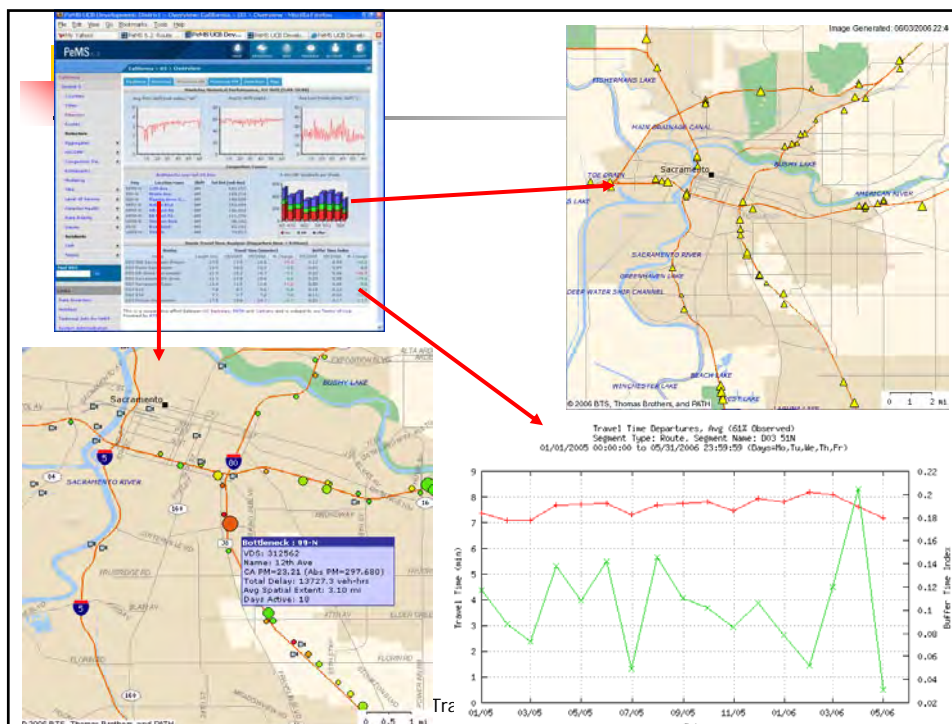
Route Travel Time Variability

- This shows average travel time per month for last 9 months
- For a given departure time (4pm)
- Also plots Buffer Time Index (BTI): amount of extra time needed to complete route 95% of time, expressed as ratio to mean TT
- We can see that travel time and BTI are both generally increasing for this particular route
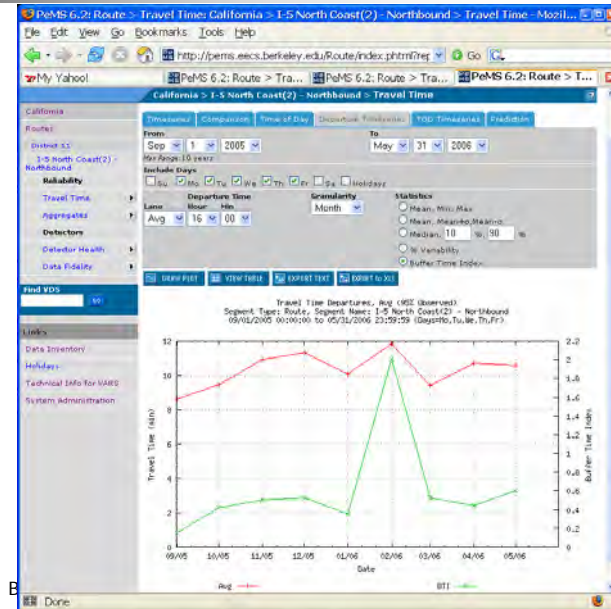
Historical Dashboard

- Focuses on only one shift (AM or PM), weekdays only
- Similar to real-time but for longer time periods
- Top: area-wide performance over last six months
  - VMT
  - VMT/VHT (Q)
  - Lost productivity
- Middle: Congestion causes
  - Bottlenecks
  - Incidents
- Bottom: Mobility analysis compared to last year
  - Average travel time for trips starting at 8:00am for the month
 - Buffer time index

Historical safety visualization

- Can perform numerous types of safety analysis on a freeway corridor
- This shows 'overlapping segment analysis'
- These overlapping bins are 5 miles wide (note that incidents are double counted)
- We can see that the postmile range 30-32 has more incidents than postmile range 49-50
- Place to look on this particular freeway for safety issues
- We've abstracted away time of day, here

Safety

- For a freeway-direction we can also view the entire distribution over both space **and** time of day
- Top is a contour plot showing frequency of incidents for all weekdays
- Around postmile 30 from 4-5pm there is a spike in the incident rate
- Bottom plot is 3D version of top
- This is a summary for a long period of time, what about the temporal characteristics of incident rates?

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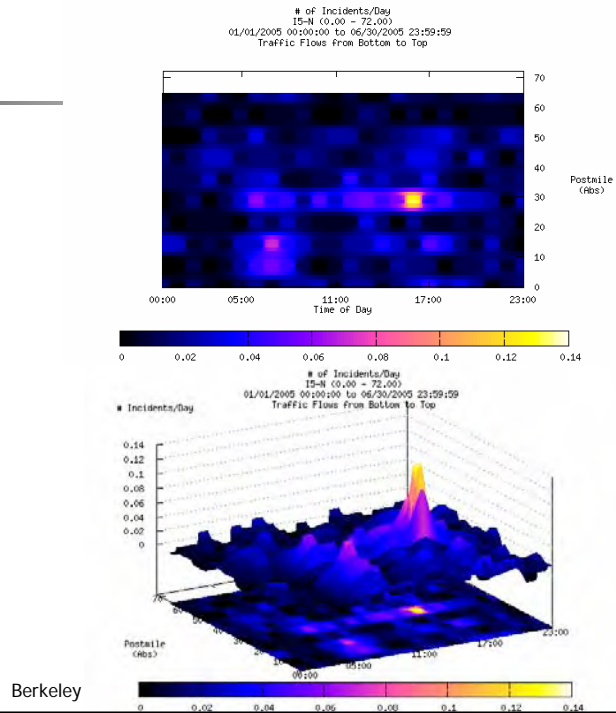
Historical safety visualization

- We can plot incident counts over time
- This plot show incidents/week for this fwy-dir
- We can see a slight increase in the # of incidents over time
- Slope = +0.36%
- Nobody likes to see incidents going up
- We might have to redirect FSP resources if this trend continues
- But what's the relationship to the demand?
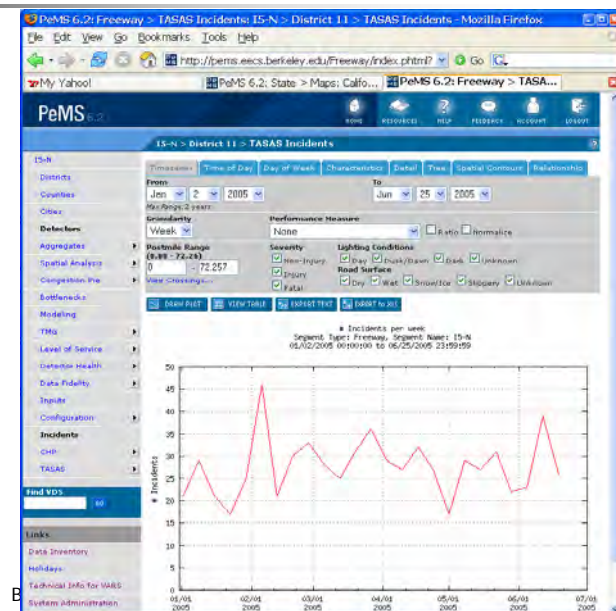
Safety

- We can add the traditional performance measure of VMT to the top plot
- We can see that demand is growing
- VMT slope = +0.56%
- On the bottom plot we have PeMS show the ratio of the # incidents to VMT
- Now incident **rate** is slightly decreasing
- # Incs/VMT slope = -0.17%
- Average of around 1.2×10^{-6} incidents/VMT
- Are these rates high versus other freeways in the district?

Berkele
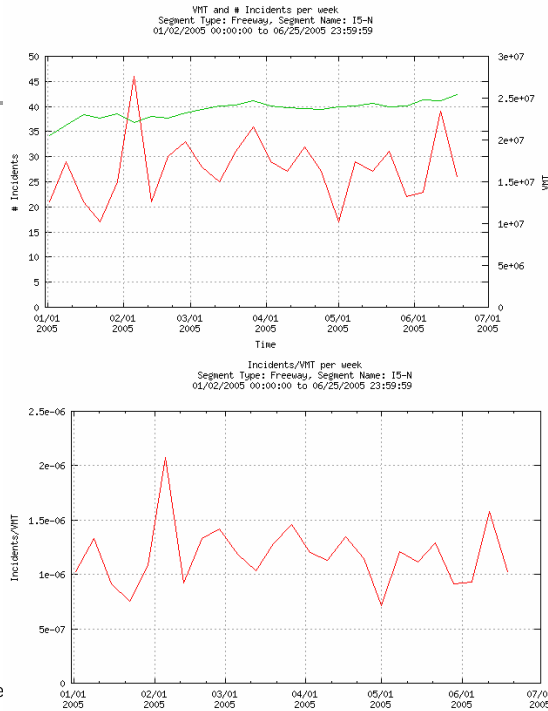
Historical safety visualization

- This is the incident analysis table for the District
- This shows for every fwy-dir the number of incidents, a performance measure (VMT was selected), and the ratio
- We sort by the resulting ratio
- SR94-W has the highest incidents/vmt during this time period, 1.68incs/Mvmt
- I5-N is way down the list

Bottleneck Identification Algorithm

- For a given region, show the sorted list of bottlenecks
- This shows in D11 (San Diego) all of the AM bottlenecks during the first two months of 2003
- Shows number of days bottleneck is active, spatial and temporal extent, and delay generated
- Links allow users to drill down to investigate characteristics and causes of bottlenecks
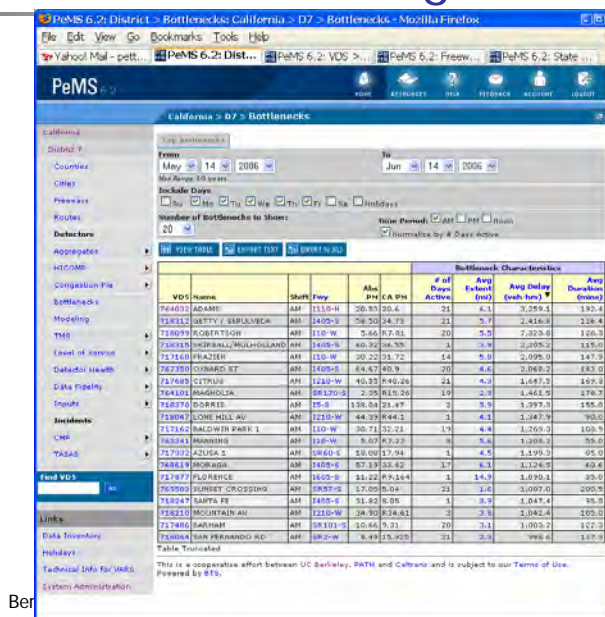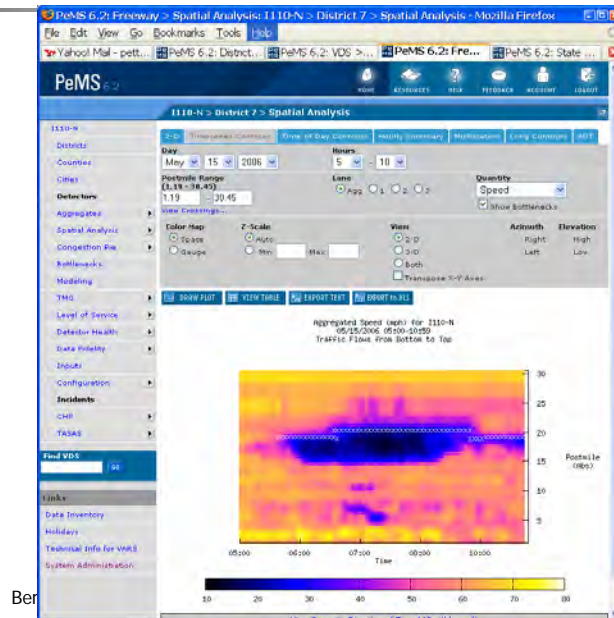

Bottlenecks – Delay

- Jumps to delay versus time of day for this location
- Can now see when the bottleneck starts and ends
- Allows users to investigate the variability of the bottleneck as it appears to users
- Is it a one-time event?
- In this example we can see that the AM bottleneck is very predictable – every day we have similar delay patterns
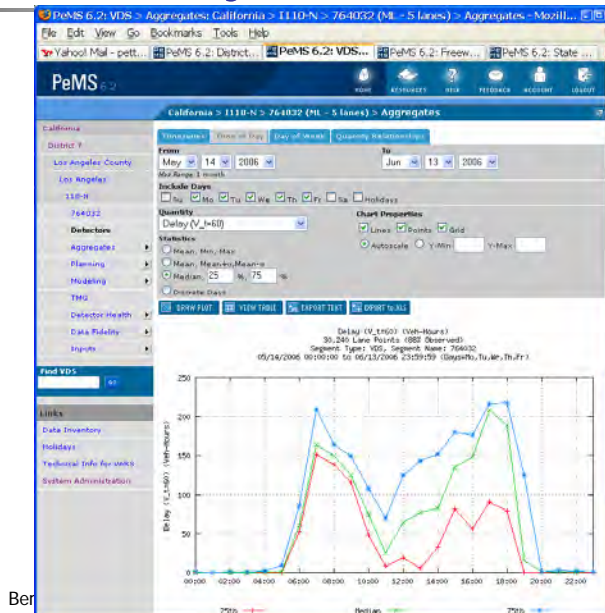
Bottlenecks – Contour Plots

- Jumps to spatial contour plots
- This is showing speed versus space and time
- Allows users to investigate the spatial and temporal extent of the bottleneck on a single day
- We mark on the plot where we think the bottleneck was activated for this day
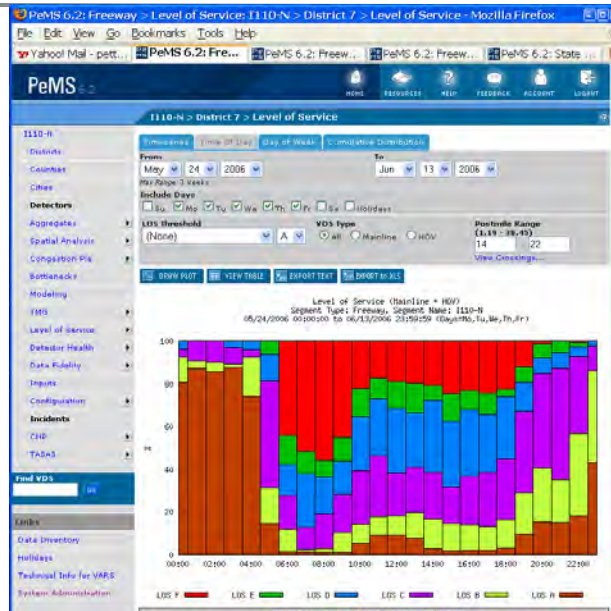

Bottlenecks – Maps

- Can jump to a map view of the location of the bottleneck
- We color and size the dots according to the delay caused and the number of days activated
- For Caltrans we tie map to other types of media
- They have a video record of every freeway in the state (PhotoLog)
- Users can see the bottleneck through these movies
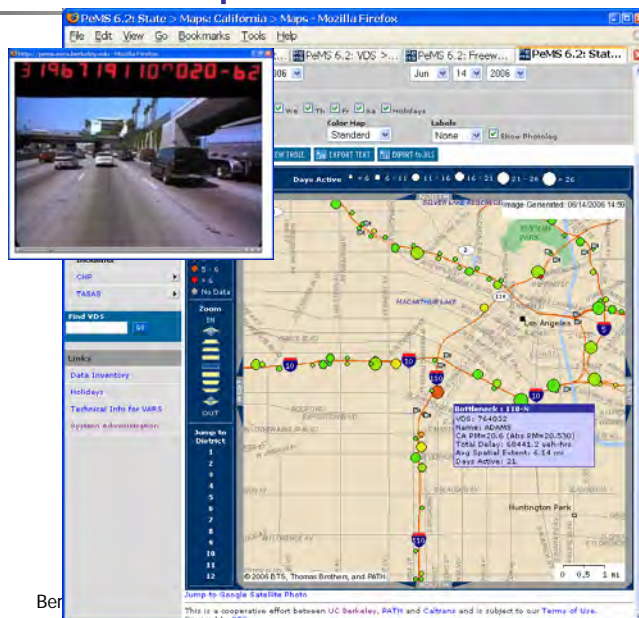
Bottlenecks – Level of Service

- Ability to perform many types of common transportation planning analysis functions
- Shows breakdown of Level of Service (LOS) over 110N from the 105 to the 10 during weekdays
- LOS ranges from A-F and represents driving conditions
- "A" is completely clear; "F" is completely packed
- We can see that the worst conditions are during the morning rush hour
- Can see the percentage of drivers experiencing each level of service

Bottlenecks – AADT

- Can investigate changes in demand at locations upstream of bottleneck
- Shows AADT per year for 1/2000 – 5/2006
- These are based on measured values, not sample counts and factor groups
- Excellent input for growth models
- Can see steady ADT over time
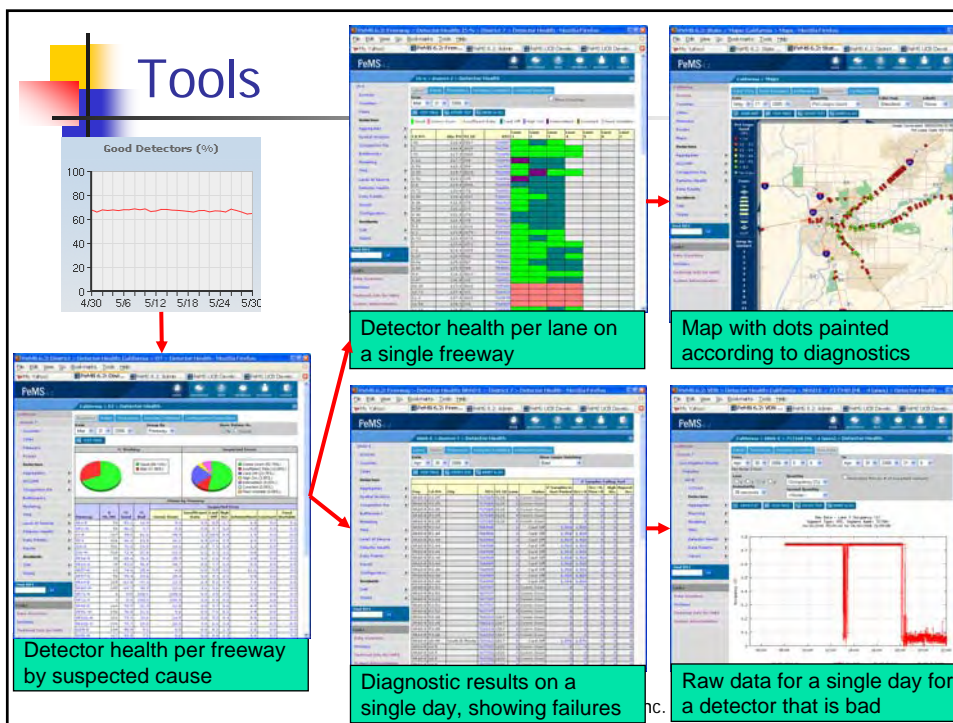- Can see all of the holidays as outliers
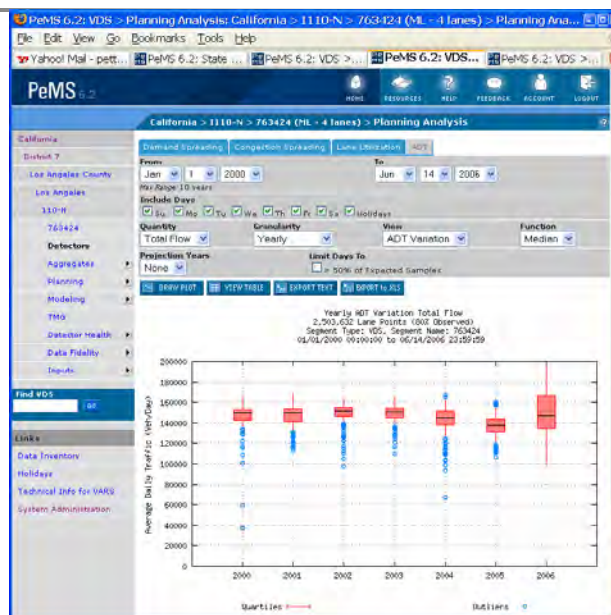
Detection Health Dashboard

- Combines real-time and historical values together
- Top: real-time
  - Samples collected today
  - Current detector health
  - Breakdown of reasons why
- Bottom: historical
  - Samples collected over time
  - Health over time
  - Reasons bad over time
- Allows for real-time actions and san see the trend of how well the district is doing over time
- This particular district, D11, has the best data quality in the State

Tools

Detector health per lane on a single freeway

Map with dots painted according to diagnostics

Detector health per freeway by suspected cause

Diagnostic results on a single day, showing failures

Raw data for a single day for a detector that is bad

Freeway Segments for SANDAG

- Wanted the ability to track performance measures for a particular section of freeway over long periods of time
  - PeMS originally did this but it was cumbersome
    - UI wasn't designed for this task
  - Reports took too long to generate
    - Database wasn't designed for this task
- We implemented a new feature for SANDAG
  - Extended system to understand "Segments" (routes)
    - Predefined postmile range on the freeway system
  - Extended processing and database to store calculated information about routes in real-time
    - Subsequent plots are much faster
  - Enhanced user interface to generate new reports
- Allowed for easy comparison between their segmentation and the way PeMS reports performance measures

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Freeway Routes Table

- A number of routes were predefined
- These matched their segmentation
- Typically from freeway to freeway
- We've extended this feature to include any route through the system
- Once it was done for one region, everybody in the State got it
- We now have routes for D7…

Freeway Segments (Routes)

- Route: Simi Valley to Downtown (118 -> 405 -> 101)
- Total of 37 miles
- We compute a number of performance measures for this route
- Travel time for every time of the day
  - Can use this to calculate reliability
- Traditional freeway performance measures (delay, vmt, vht, etc).
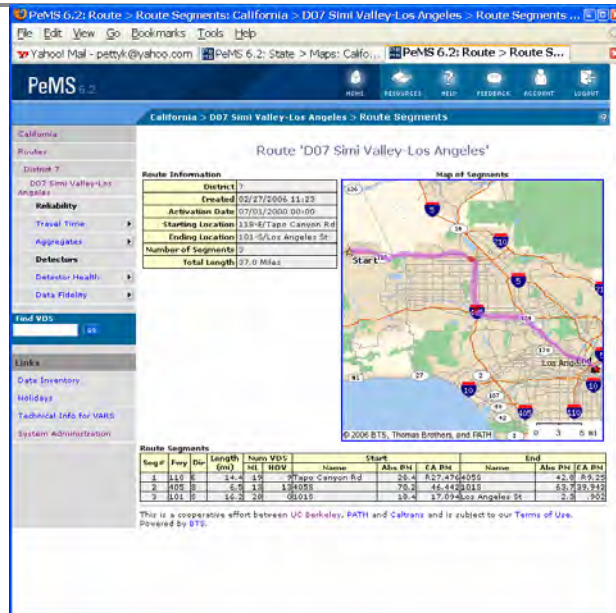

Route Travel Time Analysis

- Route: Simi Valley to Downtown (118 -> 405 -> 101)
- Shows average travel time for route starting at 6am during the weekdays
- Each point is the average for an entire quarter
- Covers the time period of 1/2002 – 6/2006
- Green line shows travel time reliability measure of Buffer Time Index (BTI): amount of extra time needed to complete route 95% of time, expressed as ratio to mean TT
- Can clearly see seasonal trends

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Route Performance Analysis

- Route: Simi Valley to Downtown (118 -> 405 -> 101)
- Show traditional freeway performance measure of delay (vehicle-hours)
- Shows average delay per month for weekdays along the route (along with 25% and 75% of distribution)
- Can clearly see the same seasonal variation that was in the route travel time plot
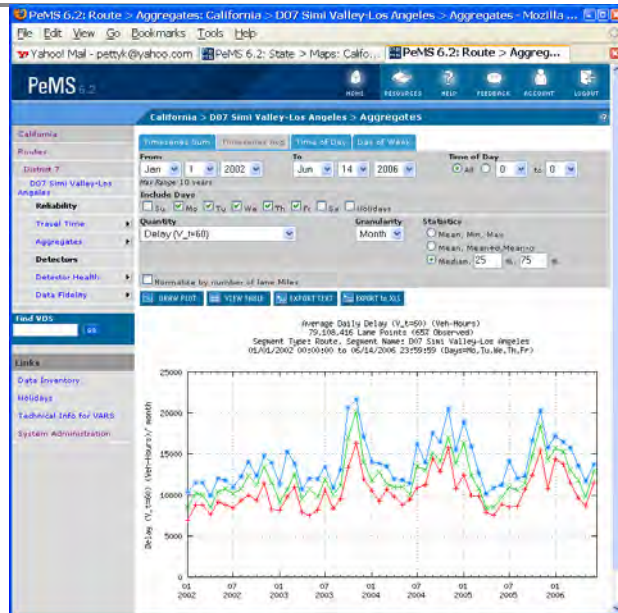
D7 VMT?

- We compute traditional performance measures, including VMT, for spatial segments (freeways, counties, districts, state)
- This plot shows the total VMT per week for all of D7 during 2006
- We also plot the number of detectors in the system (make sure we're measuring the same freeways)
- There is no drop in total VMT
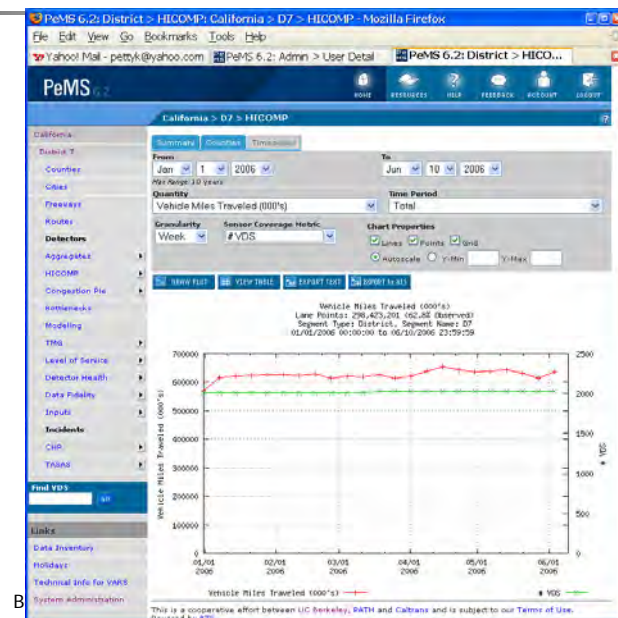
Summary

PeMS is a Real-time Archive Data Management System

- Focused on helping agencies plan for operations
- Allows for direct empirical measurements of freeway performance
- Links together
  - Traffic data archival systems
  - Real-time operational strategies
  - Freeway performance measurement

System is extendable!

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